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## (54) IMPROVEMENTS IN OR RELATING TO PIEZO-ELECTRIC VIBRATOR DRIVING CIRCUIT ARRANGEMENTS, PIEZO-ELECTRICALLY DRIVEN SOUND GENERATORS AND ELECTRONIC TIMEPIECES INCLUDING THE SAME

(71) We, KABUSHIKI KAISHA SEIKOSHA, a Japanese Company, of 6-21, 2-chome, Kyobashi, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to piezo-electric vibrator driving circuit arrangements, piezo-electrically driven sound generators, and electronic timepieces including the same and has for its main object to provide improved and simple piezo-electrical vibrator driving circuits capable of driving a vibrator with more driving force than is obtainable with known comparable driving circuits as at present in common use.

Although the invention is not limited exclusively to its application thereto, it is particularly advantageous for and primarily intended for application to the sound alarms of wrist watches and similar small electronic timepieces fitted with sound alarms.

According to one aspect of this invention there is provided a piezo-electric vibrator driving circuit arrangement including, a piezo-electric vibrator; a circuit comprising a coil and a diode in series said circuit being connected in parallel with said vibrator; a connection between one end of said circuit and a voltage supply source; and pulse actuated switching means connected to the other end of said circuit and switching ON and OFF in response to pulse signals applied thereto.

According to another aspect of this invention there is provided a piezo-electrically driven sound generator arrangement including a piezo-electric vibrator driving the sound producing element of said generator; a circuit comprising a coil and a diode in series, said circuit being connected in parallel with said vibrator; a connection between one end of said circuit and a voltage supply source; and pulse actuated switching means connected to the other end of said circuit and switching ON and OFF in response to pulse signals applied thereto.

The invention is illustrated in and explained in connection with the accompanying drawings, in which:

*Figure 1* is a circuit diagram of one embodiment of the invention;

*Figures 2, 4* and *6* are explanatory graphical figures. In Figures 2 and 6 $v$ is voltage and $t$ is time;

*Figure 3* is a face view of a piezo-electric sound producer comprising a piezo-electric ceramic vibrator stuck on a metal sound producing vibration plate; and

*Figure 5* shows a known circuit in common use for driving a piezo-electric vibrator.

Referring first to Figure 5 which, as above stated, shows a transistor circuit for driving a piezo-electric vibrator (for example for providing operating power to the coil L of a sound generator). There is a transistor $T_{r1}$ to the base of which is applied through a resistor a pulsed wave form as shown at A in the upper part of Figure 6. P1 is the piezo-electric vibrator across which occurs a damped oscillation voltage as shown at B in the lower part of Figure 6. The coil $L_1$, assumed to be the coil of a sound generator, is connected across the vibrator $P_1$ and between a point +E of positive potential and the collector of transistor $T_{r1}$. The emitter of the transistor is earthed. With this circuit, as will be apparent from Figure 6B, electric energy is given to the piezo-electric vibrator $P_1$ only during the narrow pulses occurring at the trailing edges of the pulses in Figure 6A and in consequence it is difficult to obtain much driving force for the vibrator. This is a serious defect in many cases; for example, if the driving circuit is to supply electric power to a sound generator, it is very difficult to obtain a desirably high

level of sound. Of course if the number of turns of the coil $L_1$ is increased the sound level will also be increased but the expedient of increasing the number of turns in order to increase the sound level is not a satisfactory one to adopt in cases in which the sound generator is required to be of very small size - for example in the case in which the sound generator is to be the source of the alarm sound in a wrist watch or other small timepiece fitted with an alarm. It is also possible to increase the sound level by using a transformer in the driving circuit for driving the piezo-electric vibrator, but this expedient also has the defect of involving the provision of more space than is desirable or available in many cases.

Referring now to Figure 1 which shows one embodiment of this invention, a pulsed signal as shown by the wave form A in the upper part of Figure 2 is applied at a terminal *a* and thence through a resistor R to the base of a transistor $T_{r2}$, the collector of which is connected through a coil $L_2$ (assumed to be the coil of a sound generator) and a diode *d*, poled as shown, to the positive terminal +E of a potential source. The emitter of the transistor is earthed. $P_2$ is a piezo-electric vibrator which is connected across the series circuit of coil $L_2$ and diode *d*. When the transistor $T_{r2}$ is switched ON by an applied pulse signal on its base, current flows through the coil $L_2$ and diode *d* from the DC voltage source connected to terminal +E. When, however, the transistor $T_{r2}$ is turned OFF at the trailig edge of each pulse in the wave form A, reversed induced voltage represented by the wave form B of Figure 2, is produced in the coil $L_2$ and forward biasses the diode *d*. Consequently an induced voltage is applied to the piezo-electric vibrator $P_2$. As will be seen from a comparison of the wave forms B of Figures 2 and 6, the energy given to the piezo-electric vibrator by the circuit of Figure 1 is far more than that given to it by the known circuit of Figure 5.

Experiment has confirmed the substantial nature of the improvement obtainable with the invention. The experiments were performed with a sound generator (for the sound alarm of an electronic watch) as represented in Figure 3. This generator comprised a metal vibration plate *n* on which a ceramic piezo-electric vibrator *m* was stuck. The plate *n* was made of stainless steel and had a diameter and thickness of 14 mm and 0.1 mm respectively. The ceramic piezo-electric vibrator *m* was of rectangular shape with a length, breadth and thickness of 10 mm, 2 mm and 0.2 mm respectively. The results obtained when this sound generator was driven by the known circuit of Figure 5 were compared with those obtained when it was driven by the improved circuit of Figure 1. In both circuits the coils ($L_1$ in Figure 5 and $L_2$ in Figure 1) were alike, each having 1400 turns of wire of a diameter of 0.05 mm. In both circuits voltage at +E was 1.5 volts. In the tests the metal vibration plate *n* was put in the resonant condition and the sound levels produced over a range of input pulse frequencies to the transistors ($T_{r1}$ in the case of Figure 5 and $T_{r2}$ in the case of Figure 1) were measured at a distance of 10 cms from the face of the sound generator. The results are shown graphically in Figure 4 in which the ordinates *p* are sound pressure levels in decibels (dB) and the abscissae are input frequencies *f* in KHz. Curve A shows the results obtained when the improved driving circuit of Figure 1 was used and curve B shows the results obtained when the known circuit of Figure 5 was used. The improvement obtained by this invention will be at once apparent.

In Figure 1 the switching element used was the transistor $T_{r2}$ but, as will be apparent to those skilled in the art, any similarly operating switching element known per se could be used.

As will now be appreciated the invention may be used to obtain an increased sound output from a sound generator having a given number of turns in its coil or it may be used to provide a given sound output from a sound generator having a reduced number of turns in its coil.

WHAT WE CLAIM IS:

1. A piezo-electric vibrator driving circuit arrangement including a piezo-electric vibrator; a circuit comprising a coil and a diode in series said circuit being connected in parallel with said vibrator; a connection between one end of said circuit and a voltage supply source; and pulse actuated switching means connected to the other end of said circuit and switching ON and OFF in response to pulse signals applied thereto.

2. A piezo-electrically driven sound generator arrangement including a piezo-electric vibrator driving the sound producing element of said generator; a circuit comprising a coil and a diode in series, said circuit being connected in parallel with said vibrator; a connection between one end of said circuit and a voltage supply source; and pulse actuated switching means connected to the other end of said circuit and switching ON and OFF in response to pulse signals applied thereto.

3. An arrangement as claimed in claim 1 or 2 wherein the diode is so connected as to be forwardly biased with respect to the voltage supply source.

4. An arrangement as claimed in any of the preceding claims wherein the switching means is constituted by a transistor.

5. An alarm type electronic timepiece

having a sound generating alarm driven by a driving circuit arrangement as claimed in claim 1.

6. An alarm type electronic timepiece having a piezo-electrically driven alarm sound generator arrangement as claimed in claim 2.

7. A piezo-electric vibrator driving circuit arrangement substantially as herein described and illustrated in Figure 1 of the accompanying drawings.

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FIG.1

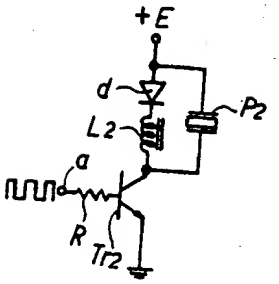


FIG.3

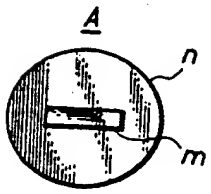


FIG.2

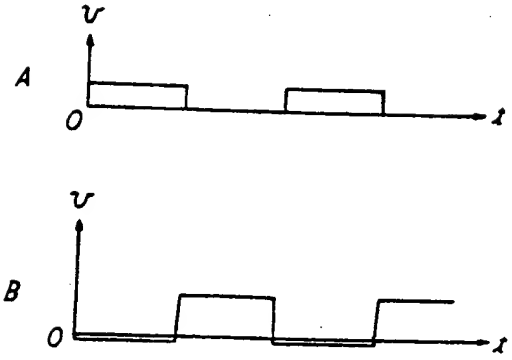

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FIG. 4

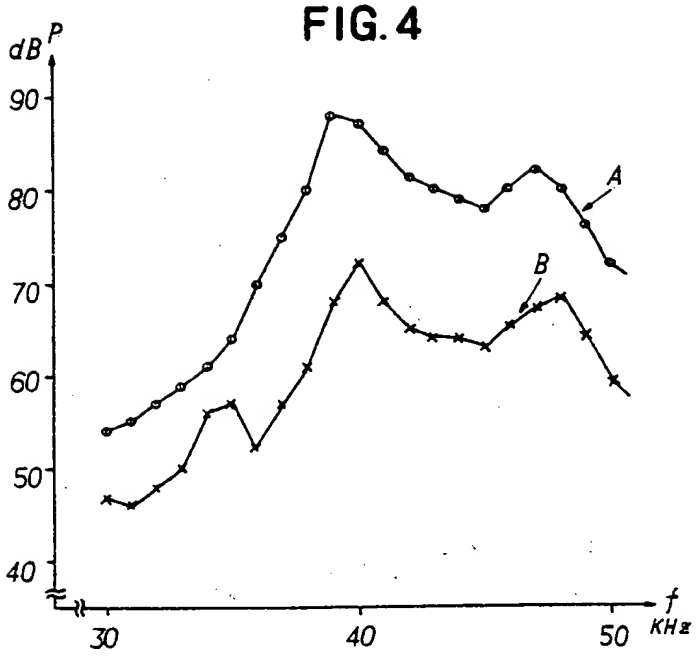


FIG. 5

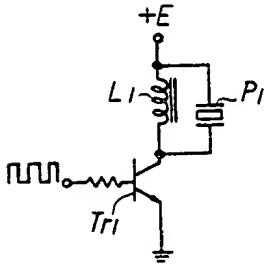


FIG. 6